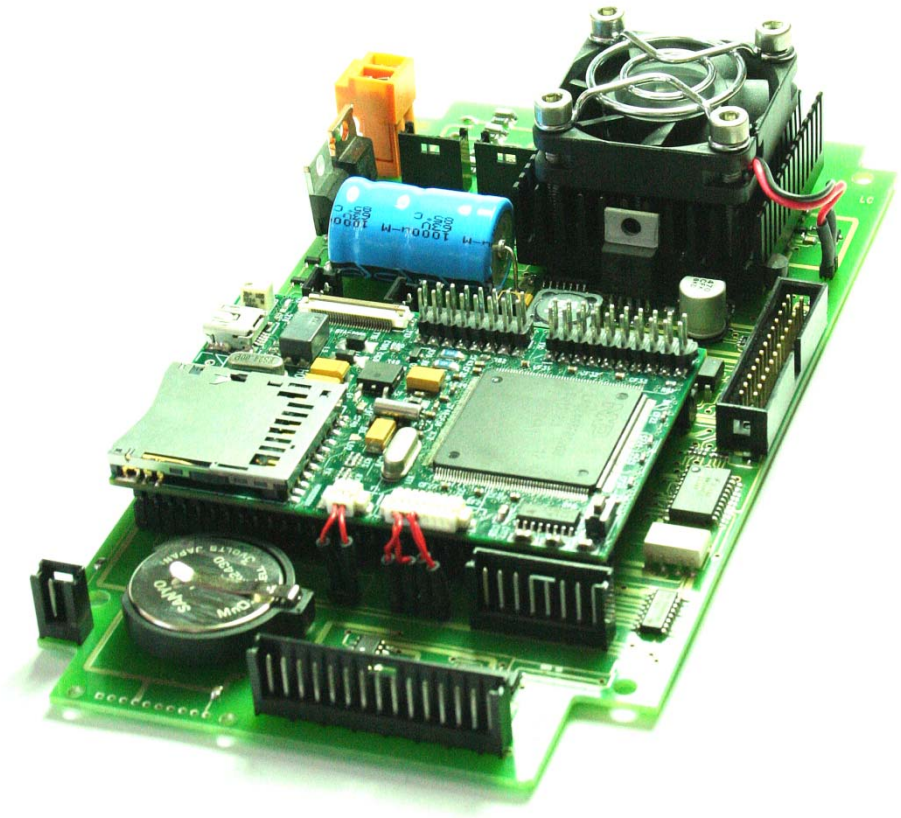

# AMS III

## *Advanced Microstepping Controller*

**User Manual Rev. 2.0.0**
**AMS III 1.0.0**
**February 2014**
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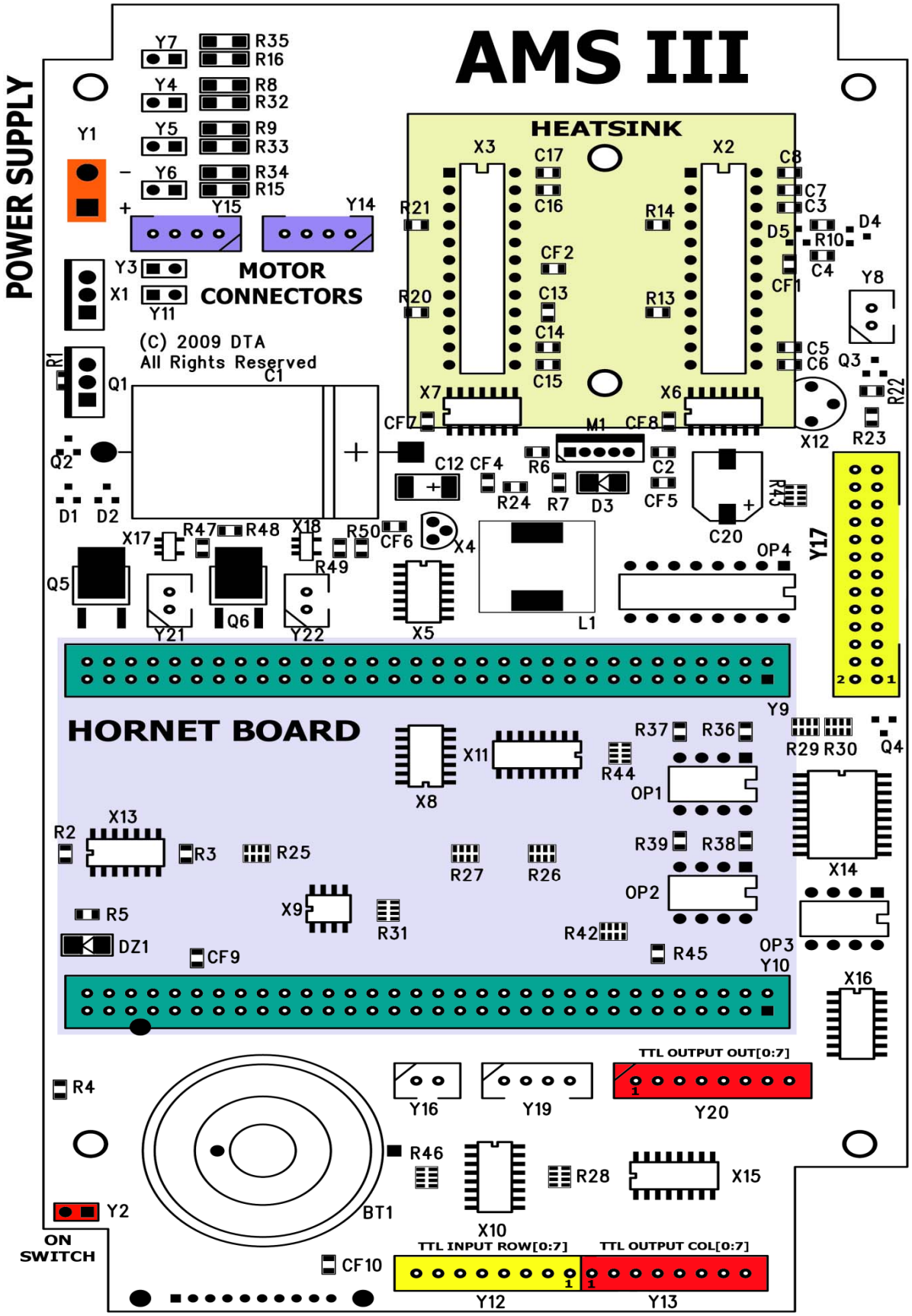
# INTRODUCTION

AMS is a control system for the management of step motors of little size up to 2.8A a phase.
It can manage two motors simultaneously, both for positioning and tracking.
AMS implements two types of architecture:

1) "open-loop": the quantization of the movement has done by the step-step motor of which is known the angular movement related to an impulse;
2) "close-loop": the quantization of the movement has done by the resolution of the encoders.

The management of the motors is based on the microstepping tecnique.
This mode allows to set the angular step by software, starting from maximum value of 200000 step/rev up to minimum of 400 step/rev.
In practice, it's as if you have a de-multiplication ratio varying electronically.
Moreover, the system allows to vary the power used by the motors from a minimum of 0% (0A) to maximum 100% (2.8A).
Another characteristic of the system is that it can execute arbitrary trackings on both the controlled axes.
At last, one of the more interesting characteristics offered by this system is the possibility to use it in cascade with other AMS devices, up to a maximum of 256 devices.
In fact, each AMS has got a own identity number (00-255), so being possible to control up to 512 motors by just one serial port.

## CONNECTORS ON THE BOARD

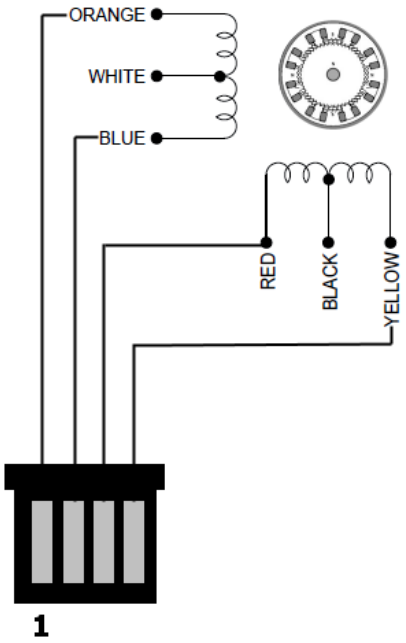


# I/O CONNECTOR Y17

| I/O SIGNALS | SCHEMATIC SIGNALS | PIN | PIN | SCHEMATIC SIGNALS | I/O SIGNALS |
|---|---|---|---|---|---|
| OPEN COLLECTOR OUTPUT | OC1 | **1** | **2** | +5V | +5V |
| TTL-OUT-1 | P4_27 | **3** | **4** | P4_26 | TTL-OUT-0 |
| TTL-OUT-3 | P4_29 | **5** | **6** | P4_28 | TTL-OUT-2 |
| TTL-IN-1 | P1_27 | **7** | **8** | P1_26 | TTL-IN-0 |
| TTL-IN-3 | P1_29 | **9** | **10** | P1_28 | TTL-IN-2 |
| RX0 | S2 | **11** | **12** | S1 | TX0 |
| (DTR) RX1 | S4 | **13** | **14** | S3 | TX1 (RTS) |
| ENCODER-0-B | INO1 | **15** | **16** | INO0 | ENCODER-0-A |
| ENCODER-1-B | INO3 | **17** | **18** | INO2 | ENCODER-0-A |
| OPTO-IN-1 | INO5 | **19** | **20** | INO4 | OPTO-IN-0 |
| L-OPTO-IN-1 | INO7 | **21** | **22** | INO6 | L-OPTO-IN-0 |
| L-OPTO-IN-3 | INO9 | **23** | **24** | INO8 | L-OPTO-IN-2 |
| GND | GND | **25** | **26** | COMOPTO | COMOPTO |

## Y14/15 MOTOR OUTPUT

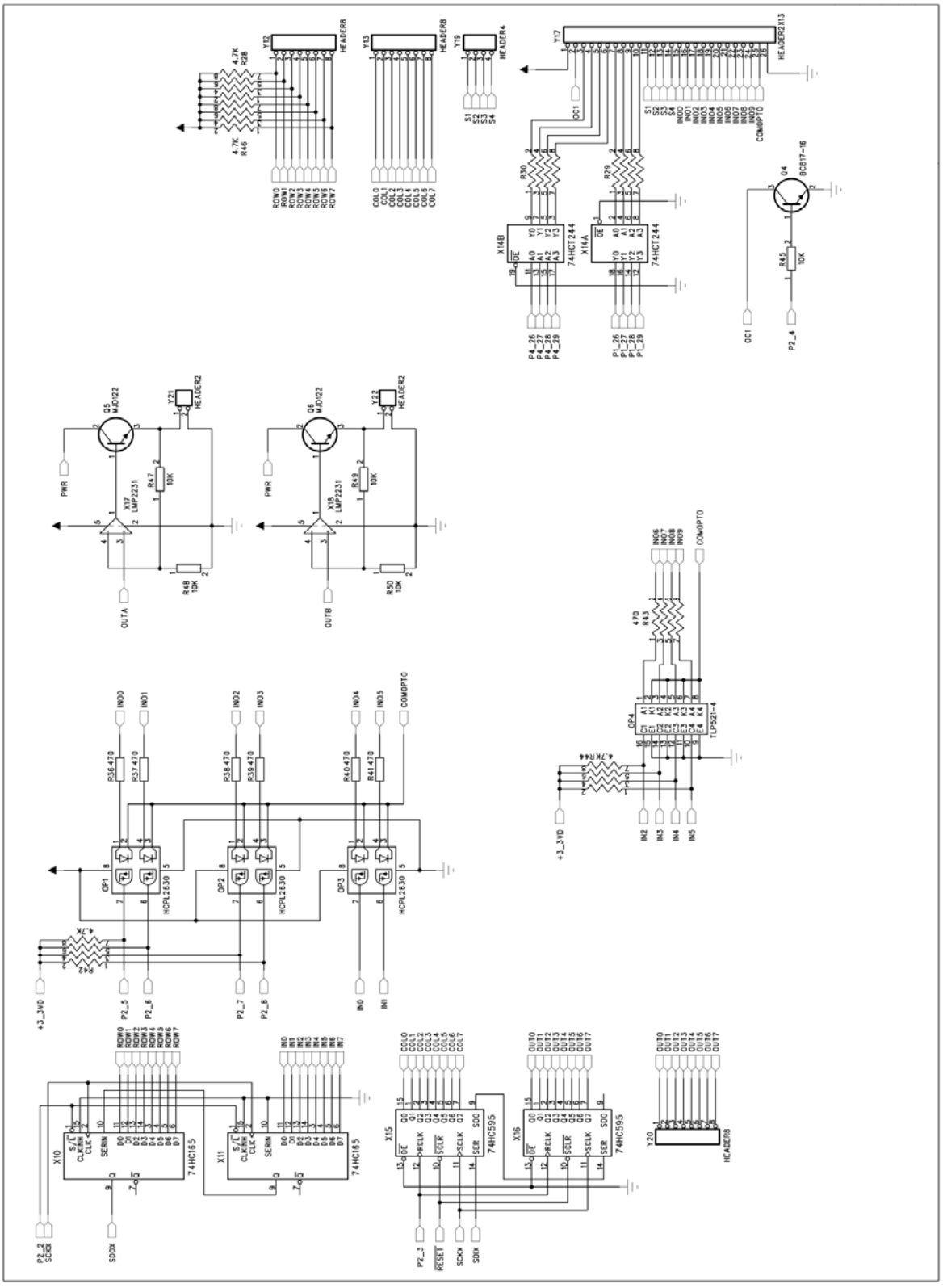
| PIN | SIGNAL | MOTOR WIRE COLOUR |
|---|---|---|
| 1 | COIL1A | Orange |
| 2 | COIL2A | Blue |
| 3 | COIL1B | Red |
| 4 | COIL2B | Yellow |




**Y2** – Power control switch. Close this contact to turn on AMS, or always leave inserted a jumper to automatically turn on with the main power.

**Y12** – TTL input ROW[0:7]. If use the keyboard MK-25 ROW[0:3] are reserved for this use.
**Y13** – TTL output COL[0:7]. If use the keyboard MK-25 COL[0:5] are reserved for this use.
**Y20** – TTL output OUT[0:7]. General purpose output.

# I/O ELECTRICAL SCHEME



# SERIAL CONNECTION

AMS works by a  RS232 serial port, the default setting is 115200,8,N,1; you can set different values by the configuration program.
AMS can be connected point-point or in cascade (in latter way, you can control up to 256 devices by just one serial port)

Personal computers offer one or more serial ports, generally of two different types: 9PIN or 25PIN (look at the image below).

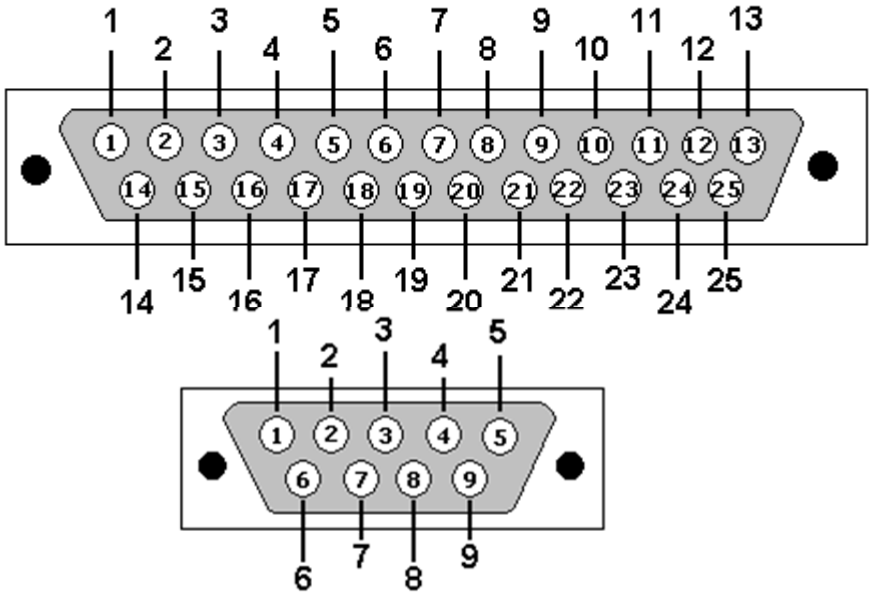
We need just three of all present signals:

1. Receive data
2. Transmit data
3. Signal ground

Depending on the type of connector, these signals are in different pins, look at the table below, where the arrangement of the pin is shown.

| DB9 | DB25 | Function |
|---|---|---|
| 1 | 8 | Data carrier detect |
| 2 | 3 | Receive data |
| 3 | 2 | Transmit data |
| 4 | 20 | Data terminal ready |
| 5 | 7 | Signal ground |
| 6 | 6 | Data set ready |
| 7 | 4 | Request to send |
| 8 | 5 | Clear to send |
| 9 | 22 | Ring indicator |

To identify the numeration of the RS232 connector's pins, the images below can be very useful:




The connector supplied requires the use of the DB9 connector according to the following arrangement:

| DB9 PC | DB9 AMS | PC Function |
|---|---|---|
| 2 | 2 | Receive data |
| 3 | 3 | Transmit data |
| 5 | 5 | Signal ground |

# SERIAL PROTOCOL

To communicate with AMS III means sending and receiving messages, typically only text messages in ASCII format.
We said "typically" since the user can define the protocol, so it is possible that he will use not-text characters for communication.

What we are going to describe is the protocol default set during the final testing of the device.

The serial protocol uses three types of fields:

1. **Control**, this type is used for:
    a. ***Identity***, it indicates the basic address identifying the AMS corresponding to the message destination; it generally consists of maximum two digits.
    b. ***Separator***, it is a character utilized to logically separate the fields between them.
    c. ***End of the message***, it is a character indicating the end of the message.
2. **Command**, it is composed by three ASCII characters and it identify the command the AMS has to run.
3. **Parameter/s** Zero or a maximum 15 specifics parameters of the command to run.

Here below a practical example of how a command sent to AMS can be composed:

| IDENTITY CONTROL | SEPARATOR CONTROL | COMMAND | SEPARATOR CONTROL | PARAMETER 1 | SEPARATOR CONTROL | ... | SEPARATOR CONTROL | PARAMETER N | END OF MESSAGE CONTROL |
|---|---|---|---|---|---|---|---|---|---|

Let's see a real message:

**0,REV$_{CR}$**

in C language the string is defined as follows:

**"0,REV\r"**

Analyzing it:
The character '0' is the identifying number of AMS, the character ',' is the separator, 'REV' is the command, '\r' e' is the character of control of end string.

If you are using only one AMS by the serial port, it is possible to skip the CONTROL IDENTITY, so the previous message becomes:

**"REV\r"**

You can even use this modality when there are many AMS connected by the same serial port; however, you have take into account that only the one directly connected to the serial port of the system is able to receive the commands.

At the contrary, it could be useful to send the same commands to all the AMS connected, you can do it indicating the sequence of characters '##' instead of the the NUMBER IDENTITY, so the message becomes:

**"##,REV\r"**

There is even the possibility to enable a control for the integrity of the messages; to do it, by a command you can enable the generation and control of a 16 bit CRC.

This type of control gives a high reliability on the integrity of the received message.

If we enable the CRC, the previous message becomes:

**0,REV,18149**$_{CR}$

The characters highlighted in yellow are the ones used for the computation of CRC.
In case the received CRC is different from the one calculated, the response is:

**0,CRC,55991**$_{CR}$

Instead, if the CRC is right, we receive:

**0,100,55487**$_{CR}$

In Appendix A you can find an example on how to calculate the CRC used by AMS.

More info on CRC at Appendix 2 or on the website:

http://en.wikipedia.org/wiki/Cyclic_redundancy_check

***It's very important to underline the first parameter indicated by AMS in the response message is its identity number.***

# COMMAND LIST

In the following pages is a complete list of commands executed by AMS.
All examples assume that:

- the number of identity of the AMS is 0
- the DECIMAL modality is active
- the separator used is the comma
- the end character is the CR (13)
- the CRC control is disabled.

Differently from above, it would change the parameter coding or response coding.

DIGITS indicates the number of hexadecimal digits, when the HEX mode is active.

For all commands that return a status these are the possible messages:

| TEXT | INDEX | DESCRIPTION |
|---|---|---|
| ACK | 0 | Successfully executed command |
| NAK | 1 | Not recognized command |
| BPN | 2 | Wrong number of parameters |
| POR | 3 | Parameter out of range |
| UNS | 4 | Not supported mode |
| CRC | 5 | CRC failure on received string |

As for the commands, the error codes can be text type or numeric index depending on the choice of the user; you can switch from one type to the other by the use of VRB command.

## REV

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| REV | | 000 | | Return the remote management program revision |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 4 | 100-1000 | Program revision |
| DETAIL | | | | |
| Command used to know the program revision. If it returns the value 100, it means 1.0.0 | | | | |
| EXAMPLE | | | | |
| ⇦ | | | ⇨ | |
| $REV_{CR}$ | | | $0,100_{CR}$ | |

## HST

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| HST | | 001 | | Return the temperature of the heatsink |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 0-255 | Heatsink temperature |
| DETAIL | | | | |
| Command used to know the operating temperature of the heatsink in degrees centigrades | | | | |
| EXAMPLE | | | | |
| ⇦ | | | ⇨ | |
| $HST_{CR}$ | | | $0,27_{CR}$ | |

## MMC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| MMC | | 002 | | Set the max current of the motors |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor.selection. |
| 1 | 4 | 0 | 2800 | Max current of the motor in mA |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Command used to set the maximum current of the motors | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| MMC,0,2000$_{CR}$ | | | | 0,ACK$_{CR}$ |

## RMC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| RMC | | 003 | | Return the maximum current of the used motors |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor.selection. |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 4 | 0-2800 | Current in use in mA |
| DETAIL | | | | |
| Command used to know the maximum current in use on the selected motor | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| RMC,0$_{CR}$ | | | | 0,2000$_{CR}$ |

## OFF

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| OFF | | | 004 | Turn off the AMS |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| | | | | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 3 | OFF | |
| DETAIL | | | | |
| By this command you can turn off the AMS by remote connection | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $OFF_{CR}$ | | | | $0,OFF_{CR}$ |

## THS

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| THS | | | 005 | Temperature threshold to start on the fan |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 1 | 2 | 0 | 99 | Temperature in degrees centigrades |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Set the temperature threshold measured on the inner heatsink in the order to turn on the fan | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $THS,55_{CR}$ | | | | $0,ACK_{CR}$ |

## RTH

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| RTH | | | 006 | Return the temperature threshold |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 0-99 | Heatsink temperature |
| DETAIL | | | | |
| Return the temperature threshold above which turns on the fan | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $RTH_{CR}$ | | | | $0,55_{CR}$ |

## EEW

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| EEW | | | 009 | Write a byte in the EEPROM at the specified address |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| 1 | 2 | 0 | 255 | Byte |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Write a byte in the EEPROM at the specified address. Attention! An area of the EEPROM is reserved to the AMS settings, a wrong writing is cause of malfunctioning | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $EEW,16384,27_{CR}$ | | | | $0,ACK_{CR}$ |

## EWW

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| EWW | | | 010 | Write a (16 bit) word in the EEPROM at the specified address |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| 1 | 4 | 0 | 65535 | Word |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Write a (16 bit) word in the EEPROM at the specified address. Attention! An area of the EEPROM is reserved to the AMS settings, a wrong writing is cause of malfunctioning | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| EWW,16384,1957$_{CR}$ | | | | 0,ACK$_{CR}$ |

## ELW

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| ELW | | | 011 | Write a (32 bit) long word in the EEPROM at the specified address |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| 1 | 8 | 0 | 4294967295 | Long Word |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Write a (32 bit) long word in the EEPROM at the specified address. Attention! An area of the EEPROM is reserved to the AMS settings, a wrong writing is cause of malfunctioning | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| ELW,16384,1961957$_{CR}$ | | | | 0,ACK$_{CR}$ |

## EDW

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| EDW | | 012 | | Write a (64 bit) floating point number in the EEPROM at the specified address |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| 1 | 8 | 1E-37 | 1E+37 | Floating point number |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Write a (64 bit) floating point number in the EEPROM at the specified address. Attention! An area of the EEPROM is reserved to the AMS settings, a wrong writing is cause of malfunctioning | | | | |
| EXAMPLE | | | | |
| ⇦ | | | ⇨ | |
| EDW,16384,1957.34567$_{CR}$ | | | 0,ACK$_{CR}$ | |

## EER

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| EER | | 013 | | Read a byte of the EEPROM at the specified address. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 0-255 | Contents of the memory |
| DETAIL | | | | |
| Read a byte of the EEPROM at the specified address (in the example given, it is not said that 206 is the content of the cell 3184). | | | | |
| EXAMPLE | | | | |
| ⇦ | | | ⇨ | |
| EER,3184$_{CR}$ | | | 0,206$_{CR}$ | |

## EWR

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| EWR | | | 014 | Read a (16 bit) word of the EEPROM at the specified address. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 4 | 0-65535 | Contents of the memory |
| DETAIL | | | | |
| Read a (16 bit) word of the EEPROM at the specified address (in the example given, it is not said that 21065 is the content of the 33174). | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| EWR,33174$_{CR}$ | | | | 0,21065$_{CR}$ |

## ELR

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| ELR | | | 015 | Read a (32 bit) long word of the EEPROM at the specified address. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 4 | 0-65535 | Contents of the memory |
| DETAIL | | | | |
| Read a (32 bit) long word of the EEPROM at the specified address (in the example given, it is not said that 65 is the content of the 1024372). | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| ELR,65$_{CR}$ | | | | 0,1024372$_{CR}$ |

## EDR

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| EDR | | 016 | | Read a real number from the EEPROM at the specified address. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 0 | 131071 | EEPROM address |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 4 | 0-65535 | Contents of the memory |
| DETAIL | | | | |
| Read a real number from the EEPROM at the specified address ((in the example given, it is not said that 1331 is the content of the 3.14159265). | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| EDR,1331$_{CR}$ | | | | 0,3.14159265$_{CR}$ |

## ILP

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| ILP | | 017 | | Read the 14 bit port |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 4 | 0-16383 | Contents of the memory |
| DETAIL | | | | |
| Read the content of the input port at 14 bit, following the order ROW[0:7],IN[0:7]. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| EDR,1331$_{CR}$ | | | | 0,3.14159265$_{CR}$ |

## OLP

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| OLP | | | 018 | Write the 16 bit port. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 4 | 0 | 65535 | 16 bit word to write on the port |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Write the port at 16 bit, the involved signals are COL[0:7],OUT[0:7] | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| OLP,1$_{CR}$ | | | | 0,ACK$_{CR}$ |

## MEN

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| MEN | | | 019 | Enable or disable the motors. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor selection |
| 1 | 2 | 0 | 1 | 0 = disable, 1 = enable |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Enable or disable the motors. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| MEN,0,1$_{CR}$ | | | | 0,ACK$_{CR}$ |

## SME

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| SME | | 020 | | Read the enabling of motors. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor selection |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 0-1 | 0 = disable, 1 = enable |
| DETAIL | | | | |
| Read the enabling of motors. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| SME,$1_{CR}$ | | | | $0,1_{CR}$ |

## FRC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| FRC | | 021 | | Set the fractioning of the motors. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 3 | Program selection |
| 1 | 2 | 1 | 500 | Fractioning (N * 400) |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Set the fractioning of the motors. Motors can execute tracking and positioning, for each operation (program) it is possible to set a different fractioning:<br>0 = Positioning axis 0<br>1 = Tracking axis 0<br>2 = Positioning axis 1<br>3 = Tracking axis 1 | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| FRC,0,$25_{CR}$ | | | | $0,ACK_{CR}$ |

## CMF

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| CMF | | 022 | | Read the set fractioning. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 3 | Program selection |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 1-500 | Frazionamento (N * 400) |
| DETAIL | | | | |
| Read the fractioning sets for each of the available program. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| CMF,0$_{CR}$ | | | | 0,25$_{CR}$ |

## RES

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| RES | | 023 | | Reset AMS |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Reset AMS | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| RES$_{CR}$ | | | | 0,ACK$_{CR}$ |

## MPF

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| MPF | | | 024 | Set the maximum positioning frequency (Hz). |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 1 | 500000 | Frequency in Hz |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Set the maximum positioning frequency (Hz). | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| MPF,50000$_{CR}$ | | | | 0,ACK$_{CR}$ |

## SMF

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| SMF | | | 025 | Read the maximum positioning frequency (Hz). |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 8 | 1-500000 | Frequency in Hz |
| DETAIL | | | | |
| Read the maximum positioning frequency (Hz). | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| SMF$_{CR}$ | | | | 0,50000$_{CR}$ |

## ESF

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| ESF | | | 026 | Set the sampling frequency (Hz) of the encoders. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 8 | 1 | 500000 | Frequency in Hz |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Set the sampling frequency (Hz) of the encoders. Typically this frequency must be 4 times the maximum positioning frequency. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| ESF,200000$_{CR}$ | | | | 0,ACK$_{CR}$ |

## SEF

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| SEF | | | 027 | Read the sampling frequency (Hz) of the encoders. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 8 | 1-500000 | Frequency in Hz |
| DETAIL | | | | |
| Read the sampling frequency (Hz) of the encoders. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| SEF$_{CR}$ | | | | 0,200000$_{CR}$ |

## ECT

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| ECT | | | 028 | Read the encoder counts. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Encoder selection |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 8 | $0\text{-}2^{32}$ | Number of counts |
| DETAIL | | | | |
| Read the encoder counts. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $ECT,0_{CR}$ | | | | $0,33212_{CR}$ |

## SEC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| SEC | | | 029 | Set the encoder counts. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Encoder selection |
| 1 | 2 | 0 | $2^{32}$ | Number of counts |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Set the encoder counts. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $SEC,0,0_{CR}$ | | | | $0,ACK_{CR}$ |

## POS

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| POS | | 030 | | Run a positioning on both axes. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Direction axis 0, 0 = CCW, 1 = CW |
| 1 | 8 | 0 | $2^{32}$ | Number of steps to run axis 0 |
| 2 | 2 | 0 | 1 | Direction axis 1, 0 = CCW, 1 = CW |
| 3 | 8 | 0 | $2^{32}$ | Number of steps to run axis 1 |
| 4 | 8 | 0 | $2^{32}$ | Starting period axis 0 |
| 5 | 8 | 0 | $2^{32}$ | Period of max speed axis 0 |
| 6 | 8 | 0 | $2^{32}$ | Starting period axis 1 |
| 7 | 8 | 0 | $2^{32}$ | Period of max speed axis 1 |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Run a positioning on both axes. Starting and maximum speed periods give the acceleration and deceleration ramp. To get the used frequencies in Hz just divide the maximum positioning speed (set with the command MPF) by the number used plus one. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| POS,0,332450,1,1234,20,2,15,2$_{CR}$ | | | | 0,ACK$_{CR}$ |

## PCT

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| PCT | | 031 | | Read the number of counts that motors have to run. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor selection 0,1 |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 8 | 0-$2^{32}$ | Number of counts |
| DETAIL | | | | |
| Once the positioning is run (command POS) it can read the countdown of the steps remaining to execute by the motors. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| PCT,0$_{CR}$ | | | | 0,39252$_{CR}$ |

## TRK

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| TRK | | 032 | | Set the tracking on both axes. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor selection |
| 1 | 8 | 0 | $2^{32}$ | Primary period |
| 2 | 8 | 0 | $2^{32}$ | Number of primary periods |
| 3 | 8 | 0 | $2^{32}$ | Secondary period |
| 4 | 8 | 0 | $2^{32}$ | Number of secondary periods |
| 5 | 8 | 0 | 1 | Direction axis 0, 0 = CCW, 1 = CW |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| This command allows you to set an arbitrary tracking on both axes. The frequency of steps is established by setting the time to be used which is equal to the maximum frequency of positioning divided the value of the period. If the frequency you want has no fractional, the primary period is equal to the secondary and the number of periods is the same; otherwise, the primary will be run for a certain period (e.g. positive deviation) and then it will be run the secondary period ( e.g. negative deviation) so that the average period is centered (in an error limit) on the value you desire. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| TRK,0,100,373,1234,20,0$_{CR}$ | | | | 0,ACK$_{CR}$ |

## ETK

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| ETK | | 033 | | Enable the tracking on an axis. |
| COMMAND | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor selection |
| 1 | 2 | 0 | 1 | Disable 0, Enable 1 |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| After sets a tracking by the command TRK, it's possible to run it or not by this command. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| ETK,0,1$_{CR}$ | | | | 0,ACK$_{CR}$ |

## TKS

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| TKS | | | 034 | Check the tracking activity. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Motor selection 0,1 |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 8 | 0-1 | 0 = Disabled, 1 = Enabled |
| DETAIL | | | | |
| Check the tracking activity. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| TKS,$0_{CR}$ | | | | $0,1_{CR}$ |

## IOP

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| IOP | | | 035 | Read the opto-isolated inputs of the encoders. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 0-15 | Status of the port |
| DETAIL | | | | |
| Generally the 4 opto-isolated bits of this port are dedicated to the encoders; however, if you use an open-loop system these inputs can be used for generic purposes. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| IOP$_{CR}$ | | | | $0,8_{CR}$ |

## SOC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| SOC | | 036 | | ON/OFF open collector output. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Disable 0, Enable 1 |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| By this command you can control the output of the open collector present on pin 1 of Y17. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| SOC,1$_{CR}$ | | | | 0,ACK$_{CR}$ |

## STO

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| STO | | 037 | | Write (4 bit wide) on the TTL amplified port. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 15 | Contents of the port |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Write (4 bit wide) on the TTL amplified port. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| STO,7$_{CR}$ | | | | 0,ACK$_{CR}$ |

## GTL

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| GTL | | 038 | | Read (4 bit wide) the inputs of the amplified port. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 0-15 | Port status |
| DETAIL | | | | |
| Read (4 bit wide) the inputs of the amplified port. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $GTL_{CR}$ | | | | $0,7_{CR}$ |

## DAC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| DAC | | 039 | | Set a tension on one by two D/A converters. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Selezione canale |
| 1 | 4 | 0 | 4095 | Tensione di uscita |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| This command allows to set the output tension of the two analogical outputs. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $DAC,0,1023_{CR}$ | | | | $0,ACK_{CR}$ |

## SRC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| SRC | | 040 | | Set the internal clock. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 4 | 1900 | 2050 | Year |
| 1 | 2 | 1 | 12 | Month |
| 2 | 2 | 1 | 31 | Day |
| 3 | 2 | 1 | 7 | Day of the week |
| 4 | 2 | 0 | 23 | Hour |
| 5 | 2 | 0 | 59 | Minute |
| 6 | 2 | 0 | 59 | Second |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Set the internal clock. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| SRC,2010,1,10,2,9,9,20$_{CR}$ | | | | 0,ACK$_{CR}$ |

## RTC

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| RTC | | 041 | | Read the internal clock. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 4 | 1900-2050 | Year |
| 2 | | 2 | 1-12 | Month |
| 3 | | 2 | 1-31 | Day |
| 4 | | 2 | 1-7 | Day of the week |
| 5 | | 2 | 0-23 | Hour |
| 6 | | 2 | 0-59 | Minute |
| 7 | | 2 | 0-59 | Second |
| DETAIL | | | | |
| Read the internal clock. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| RTC$_{CR}$ | | | | 0,2010,1,10,2,9,9,28$_{CR}$ |

## JOY

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| JOY | | | 042 | Read the status of the joystick. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| - | - | - | - | |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | 0-15 | Status of the port |
| DETAIL | | | | |
| The opto-isolated inputs OPTO[2:5] are typically used for a 4 switch joystick for manual movements | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $JOY_{CR}$ | | | | $0,1_{CR}$ |

## EDE

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | | INDEX | |
| EDE | | | 047 | Enable or disable the reading of the encoders. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 1 | Disable 0, Enable 1 |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| Enable or disable the reading of the encoders. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| $EDE,1_{CR}$ | | | | $0,ACK_{CR}$ |

## SID

| COMMAND | | | | DESCRIPTION |
|---|---|---|---|---|
| TEXT | | INDEX | | |
| SID | | 048 | | Set the AMS identifier number. |
| PARAMETER | | | | DESCRIPTION |
| # | Digits | Minimum Value | Maximum Value | |
| 0 | 2 | 0 | 255 | Identity number |
| RETURN | | | | DESCRIPTION |
| # | | Digits | Value | |
| 0 | | 2 | 0-255 | AMS identifier |
| 1 | | 2 | CODE | Operation result |
| DETAIL | | | | |
| It sets AMS identifier. Attention: the returned answer will use the new identifier. | | | | |
| EXAMPLE | | | | |
| ⇦ | | | | ⇨ |
| SID,$1_{CR}$ | | | | $1,ACK_{CR}$ |

## Appendix A1

```
// crc, previous value of crc
// c character to ad to the control
short unsigned updcrc(short unsigned crc, int c)
{
      int i;
      c <<= 8;
      for(i = 0; i < 8; i++)
      {
            if((crc ^ c) & 0x8000)
                  crc = (crc << 1) ^ 0xA001;
            else
                  crc <<= 1;
            c <<= 1;
      }
      return crc;
}

main(int argc, char *argv[])
{
      char                    filename[1024];
      short unsigned    crc16;
      unsigned                num = 0;
      if(argc > 2)
            printf("Usage:  crc [filename]");
      if(argc == 2)
            strcpy(filename, argv[1]);
      else
      {
            printf("\nEnter filename:  "); gets(filename);
      }
      if((fp = fopen(filename,"rb")) == NULL)
            printf("Can't open file");
      crc16 = 0;
      while((ch = fgetc(fp)) != EOF)
      {
            num++;
            crc16=updcrc(crc16, ch);
      }
      fclose(fp);
      printf("\nNumber of bytes = %lu\nCRC16 = %04X\n", num, crc16, );
}
```

## Appendix A2

## Cyclic redundancy check

*From Wikipedia, the free enciclopedy.*

A **cyclic redundancy check** (CRC) or **polynomial code checksum** is a non-secure hash function designed to detect accidental changes to raw computer data, and is commonly used in digital networks and storage devices such as hard disk drives. A CRC-enabled device calculates a short, fixed-length binary sequence, known as the *CRC code* or just *CRC*, for each block of data and sends or stores them both together. When a block is read or received the device repeats the calculation; if the new CRC does not match the one calculated earlier, then the block contains a *data error* and the device may take corrective action such as rereading or requesting the block be sent again.[1]

CRCs are so called because the *check* (data verification) code is a *redundancy* (it adds zero information) and the algorithm is based on *cyclic* codes. The term CRC may refer to the check code or to the function that calculates it, which accepts data streams of any length as input but always outputs a fixed-length code. CRCs are popular because they are simple to implement in binary hardware, are easy to analyse mathematically, and are particularly good at detecting common errors caused by noise in transmission channels. The CRC was invented by W. Wesley Peterson, and published in his 1961 paper.[2] The IEEE-recommended 32-bit CRC, used in Ethernet and elsewhere, appeared at a telecommunications conference in 1975.[3]

## Introduction

A CRC is an error-detecting code. Its computation resembles a long division operation in which the quotient is discarded and the remainder becomes the result, with the important distinction that the arithmetic used is the carry-less arithmetic of a finite field. The length of the remainder is always less than or equal to the length of the divisor, which therefore determines how long the result can be. The definition of a particular CRC specifies the divisor to be used, among other things.

Although CRCs can be constructed using any finite field, all commonly used CRCs employ the finite field GF(2). This is the field of two elements, usually called 0 and 1, comfortably matching computer architecture. The rest of this article will discuss only these binary CRCs, but the principles are more general.

An important reason for the popularity of CRCs for detecting the accidental alteration of data is their efficiency guarantee. Typically, an n-bit CRC, applied to a data block of arbitrary length, will detect any single error burst not longer than n bits (in other words, any single alteration that spans no more than n bits of the data), and will detect a fraction $1 - 2^{-n}$ of all longer error bursts. Errors in both data transmission channels and magnetic storage media tend to be distributed non-randomly (i.e. are "bursty"), making CRCs' properties more useful than alternative schemes such as multiple parity checks.

The simplest error-detection system, the parity bit, is in fact a trivial CRC: it uses the two bit long divisor "11".

## CRCs and data integrity

CRCs are specifically designed to protect against common types of errors on communication channels, where they can provide quick and reasonable assurance of the integrity of messages

delivered. However, they are not suitable for protecting against intentional alteration of data. Firstly, as there is no authentication, an attacker can edit a message and recalculate the CRC herself, without the substitution being detected. This is even the case when the CRC is encrypted—this was one of the design flaws of the WEP protocol.[4] Secondly, the linear properties of CRC codes allow an attacker to even keep the CRC unchanged while modifying parts of the message[5]—this also makes calculating the CRC adjustment for small changes more efficient. Nonetheless, it is still often falsely assumed that when a message and its CRC are received from an open channel and the CRC matches the message's calculated CRC then the message cannot have been altered in transit.[6]

If reliable protection against unintentional modification is desired, cryptographic hash functions should be used. However, they are much slower than CRCs, and are therefore commonly used to protect off-line data, such as files on servers or databases.

Both CRCs and cryptographic hash functions by themselves do not protect against malicious modification of data. Any application that requires protection against such attacks must use cryptographic authentication mechanisms, such as message authentication codes.

## Computation of CRC

*Main article: Computation of CRC*

To compute an n-bit binary CRC, line the bits representing the input in a row, and position the (n+1)-bit pattern representing the CRC's divisor (called a "polynomial") underneath the left-hand end of the row. Here is the first calculation for computing a 3-bit CRC:

```
11010011101100 <--- Input
1011         <--- divisor (4 Bits)
--------------
01100011101100 <--- result
```

If the input bit above the leftmost divisor bit is 0, do nothing and move the divisor to the right by one bit. If the input bit above the leftmost divisor bit is 1, the divisor is exclusive-ORed into the input (in other words, the input bit above each 1-bit in the divisor is toggled). The divisor is then shifted one bit to the right, and the process is repeated until the divisor reaches the right-hand end of the input row. Here is the last calculation:

```
00000000001110 <--- result of previous step
       1011 <--- divisor
--------------
00000000000101 <--- remainder (3 bits)
```

Since the leftmost divisor bit zeroed every input bit it touched, when this process ends the only bits in the input row that can be nonzero are the n bits at the right-hand end of the row. These n bits are the remainder of the division step, and will also be the value of the CRC function (unless the chosen CRC specification calls for some post-processing).

## Mathematics of CRC

*Main article: Mathematics of CRC*

Mathematical analysis of this division-like process reveals how to pick a divisor that guarantees good error-detection properties. In this analysis, the digits of the bit strings are thought of as the coefficients of a polynomial in some variable x—coefficients that are elements of the finite field GF(2) instead of more familiar numbers. This "polynomial trick" allows bit strings to be viewed as elements of a ring. A ring is, loosely speaking, a set of elements somewhat like numbers, that can be operated on by an operation that somewhat resembles addition and another operation that somewhat resembles multiplication, these operations possessing many of the familiar arithmetic properties of commutativity, associativity, and distributivity. Many

analytical tools commonly used with numbers also work on rings, and this is why the "polynomial" view helps the analysis.

## Specification of CRC

The concept of the CRC as an error-detecting code gets complicated when an implementer or standards committee turns it into a practical system. Here are some of the complications:

- Sometimes an implementation **prefixes a fixed bit pattern** to the bitstream to be checked. This is useful when clocking errors might insert 0-bits in front of a message, an alteration that would otherwise leave the CRC unchanged.
- Sometimes an implementation **appends n 0-bits** (n being the size of the CRC) to the bitstream to be checked before the polynomial division occurs. This has the convenience that the CRC of the original bitstream with the CRC appended is exactly zero, so the CRC can be checked simply by performing the polynomial division on the expanded bitstream and comparing the remainder with zero.
- Sometimes an implementation **exclusive-ORs a fixed bit pattern** into the remainder of the polynomial division.
- **Bit order:** Some schemes view the low-order bit of each byte as "first", which then during polynomial division means "leftmost", which is contrary to our customary understanding of "low-order". This convention makes sense when serial-port transmissions are CRC-checked in hardware, because some widespread serial-port transmission conventions transmit bytes least-significant bit first.
- **Byte order**: With multi-byte CRCs, there can be confusion over whether the byte transmitted first (or stored in the lowest-addressed byte of memory) is the least-significant byte or the most-significant byte. For example, some 16-bit CRC schemes swap the bytes of the CRC.
- **Omission of the high-order bit** of the divisor polynomial: Since the high-order bit is always 1, and since an *n*-bit CRC must be defined by an (*n* + 1)-bit divisor which overflows an *n*-bit register, some writers assume that it is unnecessary to mention the divisor's high-order bit.

## Commonly used and standardized CRCs

While cyclic redundancy checks form part of several standards, they are not themselves standardized to the point of adopting one algorithm of each degree worldwide: there are three polynomials reported for CRC-12[7], thirteen conflicting definitions of CRC-16, and six of CRC-32[8]. The polynomials usually seen are not the most efficient ones possible. Between 1993 and 2004, Koopman, Castagnoli and others surveyed the space of polynomials up to 16 bits[7], and of 24 and 32 bits,[9][10] finding examples that have much better performance (in terms of Hamming distance for a given message size) than the polynomials of earlier protocols, and published the best of these with the aim of improving the error detection capacity of future standards[10]. In particular, iSCSI and SCTP have adopted one of the findings of this research.

The popular and IEEE-recommended CRC-32 polynomial, used by Ethernet, FDDI and others, is the generating polynomial of a Hamming code and, far from being arbitrarily chosen, was selected for its error detection performance[3]. Even so, the Castagnoli CRC-32C polynomial used in iSCSI or SCTP matches its performance on messages from 58 bits–131 kbits, and outperforms it in several size ranges including the two most common sizes of Internet packet[10]. The ITU-T G.hn standard also uses CRC-32C to detect errors in the payload (although it uses CRC-16-CCITT for PHY headers).

The table below lists only the polynomials of the various algorithms in use. Any particular protocol can impose pre-inversion, post-inversion and reversed bit ordering as described above. CRCs in proprietary protocols might use a complicated initial value and final XOR for obfuscation but this does not add cryptographic strength to the algorithm.

*Note: in this table the high-order bit is omitted; see Specification of CRC above.*

| Name | Polynomial | Representations: normal / reversed / reverse of reciprocal |
|---|---|---|
| CRC-1 | $x + 1$ (most hardware; also known as *parity bit*) | 0x1 / 0x1 / 0x1 |
| CRC-4-ITU | $x^4 + x + 1$ (ITU-T G.704, p. 12) | 0x3 / 0xC / 0x9 |
| CRC-5-EPC | $x^5 + x^3 + 1$ (Gen 2 RFID[11]) | 0x09 / 0x12 / 0x14 |
| CRC-5-ITU | $x^5 + x^4 + x^2 + 1$ (ITU-T G.704, p. 9) | 0x15 / 0x15 / 0x1A |
| CRC-5-USB | $x^5 + x^2 + 1$ (USB token packets) | 0x05 / 0x14 / 0x12 |
| CRC-6-ITU | $x^6 + x + 1$ (ITU-T G.704, p. 3) | 0x03 / 0x30 / 0x21 |
| CRC-7 | $x^7 + x^3 + 1$ (telecom systems, ITU-T G.707, ITU-T G.832, MMC,SD) | 0x09 / 0x48 / 0x44 |
| CRC-8-CCITT | $x^8 + x^2 + x + 1$ (ATM HEC), ISDN Header Error Control and Cell Delineation ITU-T I.432.1 (02/99) | 0x07 / 0xE0 / 0x83 |
| CRC-8-Dallas/Maxim | $x^8 + x^5 + x^4 + 1$ (1-Wire bus) | 0x31 / 0x8C / 0x98 |
| CRC-8 | $x^8 + x^7 + x^6 + x^4 + x^2 + 1$ | 0xD5 / 0xAB / 0xEA[7] |
| CRC-8-SAE J1850 | $x^8 + x^4 + x^3 + x^2 + 1$ | 0x1D / 0xB8 / 0x8E |
| CRC-8-WCDMA | $x^8 + x^7 + x^4 + x^3 + x + 1$[12] | 0x9B / 0xD9 / 0xCD[7] |
| CRC-10 | $x^{10} + x^9 + x^5 + x^4 + x + 1$ (ATM; ITU-T I.610) | 0x233 / 0x331 / 0x319 |
| CRC-11 | $x^{11} + x^9 + x^8 + x^7 + x^2 + 1$ (FlexRay[13]) | 0x385 / 0x50E / 0x5C2 |
| CRC-12 | $x^{12} + x^{11} + x^3 + x^2 + x + 1$ (telecom systems,[14][15] ) | 0x80F / 0xF01 / 0xC07 |
| CRC-15-CAN | $x^{15} + x^{14} + x^{10} + x^8 + x^7 + x^4 + x^3 + 1$ | 0x4599 / 0x4CD1 / 0x62CC |

| | | |
|---|---|---|
| CRC-16-IBM | $x^{16} + x^{15} + x^2 + 1$ (Bisync, Modbus, USB, ANSI X3.28, many others; also known as *CRC-16* and *CRC-16-ANSI*) | 0x8005 / 0xA001 / 0xC002 |
| CRC-16-CCITT | $x^{16} + x^{12} + x^5 + 1$ (X.25, HDLC, XMODEM, Bluetooth, SD, many others; known as *CRC-CCITT*) | 0x1021 / 0x8408 / 0x8810[7] |
| CRC-16-T10-DIF | $x^{16} + x^{15} + x^{11} + x^9 + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$ (SCSI DIF) | 0x8BB7[16] / 0xEDD1 / 0xC5DB |
| CRC-16-DNP | $x^{16} + x^{13} + x^{12} + x^{11} + x^{10} + x^8 + x^6 + x^5 + x^2 + 1$ (DNP, IEC 870, M-Bus) | 0x3D65 / 0xA6BC / 0x9EB2 |
| CRC-16-DECT | $x^{16} + x^{10} + x^8 + x^7 + x^3 + 1$ (cordless telephones)[17] | 0x0589 / 0x91A0 / 0x82C4 |
| CRC-16-Fletcher | Not a CRC; see Fletcher's checksum | Used in Adler-32 A & B CRCs |
| CRC-24 | $x^{24} + x^{22} + x^{20} + x^{19} + x^{18} + x^{16} + x^{14} + x^{13} + x^{11} + x^{10} + x^8 + x^7 + x^6 + x^3 + x + 1$ (FlexRay[13]) | 0x5D6DCB / 0xD3B6BA / 0xAEB6E5 |
| CRC-24-Radix-64 | $x^{24} + x^{23} + x^{18} + x^{17} + x^{14} + x^{11} + x^{10} + x^7 + x^6 + x^5 + x^4 + x^3 + x + 1$ (OpenPGP) | 0x864CFB / 0xDF3261 / 0xC3267D |
| CRC-30 | $x^{30} + x^{29} + x^{21} + x^{20} + x^{15} + x^{13} + x^{12} + x^{11} + x^8 + x^7 + x^6 + x^2 + x + 1$ (CDMA) | 0x2030B9C7 / 0x38E74301 / 0x30185CE3 |
| CRC-32-Adler | Not a CRC; see Adler-32 | See Adler-32 |
| CRC-32-IEEE 802.3 | $x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$ (V.42, MPEG-2, PNG[18], POSIX cksum) | 0x04C11DB7 / 0xEDB88320 / 0x82608EDB[10] |
| CRC-32C (Castagnoli) | $x^{32} + x^{28} + x^{27} + x^{26} + x^{25} + x^{23} + x^{22} + x^{20} + x^{19} + x^{18} + x^{14} + x^{13} + x^{11} + x^{10} + x^9 + x^8 + x^6 + 1$ (iSCSI & SCTP, G.hn payload) | 0x1EDC6F41 / 0x82F63B78 / 0x8F6E37A0[10] |
| CRC-32K (Koopman) | $x^{32} + x^{30} + x^{29} + x^{28} + x^{26} + x^{20} + x^{19} + x^{17} + x^{16} + x^{15} + x^{11} + x^{10} + x^7 + x^6 + x^4 + x^2 + x + 1$ | 0x741B8CD7 / 0xEB31D82E / 0xBA0DC66B[10] |
| CRC-32Q | $x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^8 + x^7 + x^5 + x^3 + x + 1$ (aviation; AIXM[19]) | 0x814141AB / 0xD5828281 / 0xC0A0A0D5 |
| CRC-64-ISO | $x^{64} + x^4 + x^3 + x + 1$ (HDLC — ISO 3309, Swiss-Prot/TrEMBL; considered weak for hashing[20]) | 0x000000000000001B / 0xD800000000000000 / 0x8000000000000000D |

| | | |
|---|---|---|
| CRC-64-ECMA-182 | $x^{64} + x^{62} + x^{57} + x^{55} + x^{54} + x^{53} + x^{52} + x^{47} + x^{46} + x^{45} + x^{40} + x^{39} + x^{38} + x^{37} + x^{35} + x^{33} + x^{32} + x^{31} + x^{29} + x^{27} + x^{24} + x^{23} + x^{22} + x^{21} + x^{19} + x^{17} + x^{13} + x^{12} + x^{10} + x^{9} + x^{7} + x^{4} + x + 1$ (as described in ECMA-182 p. 51) | 0x42F0E1EBA9EA3693 / 0xC96C5795D7870F42 / 0xA17870F5D4F51B49 |

Known to exist, but technologically defunct—mainly replaced by cryptographic hash functions:

- CRC-128 (IEEE)
- CRC-256 (IEEE)

## Designing CRC polynomials

The selection of generator polynomial is the most important part of implementing the CRC algorithm. The polynomial must be chosen to maximise the error detecting capabilities while minimising overall collision probabilities.

The most important attribute of the polynomial is its length (the number of the highest nonzero coefficient), because of its direct influence of the length of the computed checksum.

The most commonly used polynomial lengths are:

- 9 bits (CRC-8)
- 17 bits (CRC-16)
- 33 bits (CRC-32)
- 65 bits (CRC-64)

The design of the CRC polynomial depends on what is the maximum total length of the block to be protected (data + CRC bits), the desired error protection features, and the type resources for implementing the CRC as well as the desired performance. A common misconception is that the "best" CRC polynomials are derived from either an irreducible polynomial or an irreducible polynomial times the factor $(1 + x)$,[*citation needed*] which adds to the code the ability to detect all errors affecting an odd number of bits. In reality, all the factors described above should enter in the selection of the polynomial.

The advantage of choosing say a primitive polynomial as the generator for a CRC code is that the resulting code has maximal total block length; in here if r is the degree of the primitive generator polynomial then the maximal total blocklength is equal to $2^r - 1$, and the associated code is able to detect any single bit or double errors. If instead, we used as generator polynomial $g(x) = p(x)(1 + x)$, where $p(x)$ is a primitive polynomial of degree $r - 1$, then the maximal total blocklength would be equal to $2^{r-1} - 1$ but the code would be able to detect single, double, and triple errors.

A polynomial $g(x)$ that admits other factorizations may be chosen then so as to balance the maximal total blocklength with a desired error detection power. A powerful class of such polynomials, which subsumes the two examples described above, is that of BCH codes. Regardless of the reducibility properties of a generator polynomial of degree r, assuming that it includes the "+1" term, such error detection code will be able to detect all error patterns that are confined to a window of r contiguous bits. These patterns are called "error bursts".

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